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November 2006

SPACE ACQUISITIONS

DOD Needs to Take More Action to Address Unrealistic Initial Cost Estimates of Space Systems

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November 2006

SPACE ACQUISITIONS

DOD Needs to Take More Action to Address Unrealistic Initial Cost Estimates of Space Systems

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Highlights

Highlights of GAO-07-96, a report to Subcommittee on Strategic Forces, Committee on Armed Services, House of Representatives

Why GAO Did This Study

Estimated costs for the Department of Defense's (DOD) major space acquisition programs have increased by about $12.2 billion from initial estimates for fiscal years 2006 through 2011. Cost growth for ongoing Air Force programs above initial estimates accounts for a substantial portion of this 44 percent increase. In light of the role that optimistic estimating is believed to have played in exacerbating space acquisition cost growth, you requested that we examine (1) in what areas space system acquisition cost estimates have been unrealistic and (2) what incentives and pressures have contributed to the quality and usefulness of cost estimates for space system acquisitions.

What GAO Recommends

GAO recommends that DOD take a number of actions to increase the likelihood that independent, more realistic cost estimates will be developed and utilized.

DOD concurred with the overall findings of this report and provided information on the specific actions it was already taking to improve the Air Force's cost-estimating capability.

www.gao.gov/cgi-bin/getrpt?GAO-07-96.

To view the full product, including the scope and methodology, click on the link above. For more information, contact Cristina T. Chaplain at (202) 512-4841 or chaplainc@gao.gov.

What GAO Found

Costs for DOD space acquisitions over the past several decades have consistently been underestimated—sometimes by billions of dollars. For example, Space Based Infrared System High program costs were originally estimated at $4 billion, but the program is now estimated to cost over $10 billion. Estimated costs for the National Polar-orbiting Operational Satellite System program have grown from almost $6 billion at program start to over $11 billion.

For the most part, cost growth has not been caused by poor cost estimating, but rather the tendency to start programs before knowing whether requirements can be achieved within available resources—largely because of pressures to secure funding. At the same time, however, unrealistic program office cost estimates have exacerbated space acquisition problems. Specifically, with budgets originally set at unrealistic amounts, DOD has had to resort to continually shifting funds to and from programs, and such shifts have had costly, reverberating effects.

Our analyses of six ongoing space programs found that original cost estimates were particularly unrealistic about the promise of savings from increased contractor program management responsibilities, the constancy and availability of the industrial base, savings that could be accrued from heritage systems, the amount of weight growth that would occur during a program, the availability of mature technology, the stability of funding, the stability of requirements, and the achievability of planned schedules. At times, estimates that were more realistic in these areas were available to the Air Force, but they were not used.

Cost-estimating and program officials we spoke with identified a number of factors that have contributed to this condition, in addition to larger pressures to produce low estimates that are more likely to win support for funding.

- Although the National Security Space Acquisition policy requires that independent cost estimates be prepared by bodies outside the acquisition chain of command, it does not require that they be relied upon to develop program budgets.
- While the policy requires that cost estimates be updated at major acquisition milestones, significant events, such as changes in the industrial base or funding, have occurred between milestones.
- Within space system acquisitions, cost-estimating officials believe that their roles and responsibilities are not clear and the cost-estimating function is fragmented.
- Cost-estimating resources have atrophied over the years because of previous downsizing of the workforce, making resources such as staff and data inadequate and the Air Force more dependent on support contractors for the estimating function.

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Abbreviations

ACAT	Acquisition Category
AEHF	Advanced Extremely High Frequency
AFCAA	Air Force Cost Analysis Agency
APB	Acquisition Program Baseline
CAIG	Cost Analysis Improvement Group
DOD	Department of Defense
DMSP	Defense Meteorological Satellite Program
EELV	Evolved Expendable Launch Vehicle
GEO	geosynchronous earth orbit
GPS	Global Positioning System
HEO	highly elliptical orbit
KDP	key decision point
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NRO	National Reconnaissance Office
NSA	National Security Agency
SBIRS	Space Based Infrared System
SMC	Space and Missile Systems Center
TRL	Technology Readiness Level
TSAT	Transformational Satellite Communications System
TSPR	Total System Performance Responsibility
WGS	Wideband Gapfiller Satellites

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Accountability * Integrity * Reliability

United States Government Accountability Office
Washington, DC 20548

November 17, 2006

The Honorable Terry Everett
Chairman
The Honorable Silvestre Reyes
Ranking Minority Member
Subcommittee on Strategic Forces
Committee on Armed Services
House of Representatives

Estimated costs for the Department of Defense's (DOD) major space acquisition programs have increased a total of about $12.2 billion—or nearly 44-percent—above initial estimates for fiscal years 2006 through 2011. In some cases, current estimates of costs are more than double the original estimates. For example, the Space Based Infrared System (SBIRS) High program was originally estimated to cost about $4 billion, but is now estimated to cost over $10 billion. The National Polar-orbiting Operational Satellite System (NPOESS) program was originally estimated to cost almost $6 billion but is now over $11 billion. Such growth has had a dramatic impact on DOD's overall space portfolio. To cover the added costs of poorly performing programs, DOD has shifted scarce resources away from other programs, creating a cascade of cost and schedule inefficiencies.

Our work has identified a variety of reasons for this cost growth, most notably that weapons programs are incentivized to produce and use optimistic cost and schedule estimates in order to successfully compete for funding and that DOD starts its space programs too early, that is, before it has assurance that the capabilities it is pursuing can be achieved within available resources and time constraints. At the same time, however, this cost growth was partly due to the fact that DOD used low cost estimates to establish programs' budgets and later found it was necessary to make funding shifts that had costly, reverberating effects. In 2003, a DOD study of space acquisition problems found that the space acquisition system is strongly biased to produce unrealistically low cost estimates throughout the process. The study found that most programs at the time of contract initiation had a predictable cost growth of 50 to 100 percent. The study also found that the unrealistically low projections of program cost and lack of provisions for management reserve seriously distorted management decisions and program content, increased risks to

mission success, and virtually guaranteed program delays. We have found that most of these conditions exist in many DOD programs.

Given concerns about the role optimistic cost estimating has played in exacerbating space acquisition problems, you requested that we examine (1) in what areas space system acquisitions cost estimates have been unrealistic and (2) what incentives and pressures have contributed to the quality and usefulness of cost estimates for space system acquisitions.

In conducting our work, we developed case studies of six ongoing major space acquisition programs that included analysis of cost and other program documentation. These include the Advanced Extremely High Frequency (AEHF) satellite program (communications satellites), the Evolved Expendable Launch Vehicle (EELV) (satellite launch systems), the Global Positioning System (GPS) IIF (navigational satellites), the National Polar-orbiting Operational Environmental Satellite System (weather and environmental monitoring satellites), the Space Based Infrared System High (missile detection satellites), and the Wideband Gapfiller Satellites (WGS) (communication satellites). We also spoke with officials from DOD, the Air Force, and contractor offices and analyzed DOD and Air Force acquisition and cost-estimating policies. In addition, we obtained input on our findings from a panel of cost-estimating experts who work within the Office of the Secretary of Defense as well as the Air Force. Additional information on our scope and methodology is in appendix I. We conducted our work from August 2005 to October 2006 in accordance with generally accepted government auditing standards.

Results in Brief

Our analyses of six ongoing space programs found that original cost estimates were unrealistic in a number of areas, specifically, savings from increased contractor program management responsibilities, the constancy and availability of the industrial base, savings that could be accrued from heritage systems, the amount of weight growth that would occur during a program, the availability of mature technology, the stability of funding, the stability of requirements, and the achievability of planned schedules. At times, estimates that were more realistic in these areas were available to the Air Force, but they were not used so that programs could sustain support amid competition for funding.

Cost-estimating and program officials we spoke with identified a number of factors that have contributed to low estimates in addition to the larger pressures to win support for funding. For example, although the National Security Space Acquisition policy requires independent cost estimates that

are prepared by bodies outside the acquisition chain of command, such estimates have not always been relied upon for program decisions or to develop program budgets. In addition, while the policy requires that independent cost estimates be prepared or updated at major acquisition milestones, significant events, such as changes in the industrial base or funding, have occurred between milestones. Moreover, within space system acquisitions, cost-estimating officials believe that their roles and responsibilities are not clear, and the cost-estimating function is fragmented. Finally, according to Air Force officials, cost-estimating resources have atrophied over the years because of the previous downsizing of the workforce, making resources such as staff and data inadequate and the Air Force more dependent on support contractors for the estimating function.

While the Air Force has taken steps recently to emphasize the use of independent cost estimates, it has not made additional changes needed to enhance the quality of cost estimates. We are making recommendations aimed at instituting these actions. DOD agreed with most of our recommendations, and is taking a number of actions to improve the Air Force's cost-estimating capability for space programs. DOD expressed concern that requiring officials involved in milestone decisions to document and justify their choice of cost estimates would reduce the milestone decision authority's future decision-making flexibility. While we recognize the importance of decision-making flexibility, we believe that more transparency in DOD's decision making is needed given the poor foundation of choices made in the past on space programs.

Background

Estimates of the total cost of a program are critical components in the acquisition process because they help decision makers decide among competing options and evaluate resource requirements at key decision points. All military services prepare life-cycle cost estimates in support of their acquisition programs that attempt to identify all costs of an acquisition program, from initiation through development, production, and disposal of the resulting system at the end of its useful life. These estimates serve two primary purposes. First, they are used at acquisition program milestone and decision reviews to assess whether the acquisition is affordable or consistent with the military services' and DOD's overall long-range funding, investment, and force structure plans. Second, they form the basis for budget requests to Congress. A realistic estimate of projected costs makes for effective resource allocation, and it increases the probability of a project's success.

The requirements and guidance for cost estimating are specified in statute and in DOD policies. By law, there is a requirement that an independent life-cycle cost estimate be considered by the milestone decision authority before approving system development and demonstration, or production and deployment, of a major defense acquisition program.[1] The statute requires DOD to prescribe regulations governing the content and submission of such estimates and that the estimate be prepared by (1) an office or other entity that is not under the supervision, direction, or control of the military department, DOD agency, or other DOD component directly responsible for carrying out the development or acquisition of the program, or (2) by an office or other entity that is not directly responsible for carrying out the development or acquisition of the program if the decision authority for the program has been delegated to an official of a military department, DOD agency, or other DOD component.[2] The statute specifies that the independent estimate is to include all costs of development, procurement, military construction, and operations and support, without regard to funding source or management control.[3] DOD policy assigns specific responsibility for fulfilling the requirement of an independent cost estimate to the Office of the Secretary of Defense Cost Analysis Improvement Group (CAIG) for any major defense acquisition program and major system that are subject to review by the Defense Acquisition Board of the Defense Space Acquisition Board.[4] These board reviews address major defense acquisition programs (including space programs) that are designated as acquisition category (ACAT) ID, pre-major defense acquisition programs, or ACAT IC programs (see app. II for a description of acquisition categories ID and IC). The CAIG independent cost estimate is prepared for milestone (known as key decision point in space programs) B (program start, or preliminary design for space programs), and C (low-rate initial production or build approval for space programs). In addition, the milestone decision authority may request the CAIG to prepare other independent cost estimates, or conduct other ad hoc cost assessments for programs subject to its review and oversight. The CAIG serves as the principal advisory body to the milestone decision authority on all matters concerning an acquisition program's life-cycle

[1] 10 U.S.C. § 2434 (2000).

[2] 10 U.S.C. § 2434(b)(1)(A).

[3] 10 U.S.C. § 2434(b)(1)(B).

[4] DOD Directive 5000.04, Cost Analysis Improvement Group at ¶ 2 (Aug. 2006); DOD Instruction 5000.2, Enclosure 6, Resource Estimation (May 2003).

cost, and is given general responsibilities for establishing DOD policy guidance on a number of matters relating to cost estimating.

Since 2003, cost estimating for major space system acquisitions has been governed by the National Security Space Acquisition Policy.[5] Under this policy, the CAIG is responsible for and leads the development of independent cost analyses of major space acquisition programs.[6] Fulfilling the requirement that an independent cost estimate be developed by an organization independent of the program office and the acquisition chain of command, the CAIG does so in support of a distinct Defense Space Acquisition Board, with the Under Secretary of the Air Force as the milestone decision authority.[7] The CAIG is to prepare independent cost analyses for space acquisition programs by augmenting its own staff with an independent team of qualified personnel from across the space community, including the Air Force Cost Analysis Agency (AFCAA) and the cost estimating organizations of the Air Force Space Command and the Air Force Space and Missile Systems Center. In addition to the independent cost estimates, individual program offices also prepare cost estimates for their acquisition programs. The independent CAIG cost estimate is designed to assess the program office estimate and ensure realistic cost estimates are considered. In addition, although not required in the space acquisition policy, in some cases a cost analysis is prepared by an Air Force service organization, such as the Air Force Cost Analysis Agency.

Past GAO Findings on Space Cost Growth

For fiscal years 2006 through 2011, estimated costs for DOD's major space acquisition programs have increased a total of about $12.2 billion above initial estimates. For example, the cost estimate for the SBIRS High program rose from about $4 billion at the start of development in October 1996 to over $10 billion in September 2005, and costs are expected to rise further. In addition, the cost estimate for the NPOESS program grew from

[5] National Security Space Acquisition Policy 03-01 (revised December 2004).

[6] National Security Space Acquisition Policy at Appendix 3.2.

[7] Recently, the Under Secretary of Defense for Acquisition, Technology and Logistics withdrew its delegation of milestone decision authority from the Air Force. As a result, although some acquisition authority was returned to the Air Force, the Under Secretary of Defense for Acquisition, Technology and Logistics is the current milestone decision authority for major space system acquisitions. It is not known when or if this role will be placed back within the Air Force.

about $5.9 billion at program start in 2002 to nearly $11.4 billion currently, according to the CAIG's latest estimate.

Our past work has identified a number of causes behind the cost growth and related problems, but several consistently stand out. First, on a broad scale, DOD starts more weapon programs than it can afford, creating a competition for funding that encourages low cost estimating, optimistic scheduling, overpromising, suppressing of bad news, and, for space programs, forsaking the opportunity to identify and assess potentially better alternatives. Programs focus on advocacy at the expense of realism and sound management. Invariably, with too many programs in its portfolio, DOD is forced to continually shift funds to and from programs—particularly as programs experience problems that require more time and money to address. Such shifts, in turn, have had costly, reverberating effects.

Second, as we have previously testified and reported, DOD starts its space programs too early, that is, before it has the assurance that the capabilities it is pursuing can be achieved within available resources and time constraints. This tendency is caused largely by the funding process, since acquisition programs attract more dollars than efforts concentrating solely on proving technologies. Nevertheless, when DOD chooses to extend technology invention into acquisition, programs experience technical problems that require large amounts of time and money to fix. Moreover, when this approach is followed, cost estimators are not well positioned to develop accurate cost estimates because there are too many unknowns. Put more simply, there is no way to estimate how long it would take to design, develop, and build a satellite system when critical technologies planned for that system are still in relatively early stages of discovery and invention.

A companion problem for space systems is that programs have historically attempted to satisfy all requirements in a single step, regardless of the design challenge or the maturity of the technologies necessary to achieve the full capability. Increasingly, DOD has preferred to make fewer, but heavier, large and complex satellites that perform a multitude of missions rather than larger constellations of smaller, less complex satellites that gradually increase in sophistication. This has stretched technology challenges beyond current capabilities in some cases and vastly increased the complexities related to software—a problem that affected SBIRS High and AEHF, for example.

In addition, several of the space programs included in our case studies, began in the late 1990s, when DOD structured contracts in a way that reduced oversight and shifted key decision-making responsibility onto contractors. This approach—known as Total System Performance Responsibility, or TSPR—was intended to facilitate acquisition reform and enable DOD to streamline a cumbersome acquisition process and leverage innovation and management expertise from the private sector. However, DOD later found that this approach magnified problems related to requirements creep and poor contractor performance. In addition, under TSPR, the government decided not to obtain certain cost data, a decision that resulted in the government having even less oversight of the programs and limited information from which to manage the programs. Further, the reduction in government oversight and involvement led to major reductions in various government capabilities, including cost-estimating and systems-engineering staff. The loss of cost-estimating and systems-engineering staff in turn led to a lack of technical data needed to develop sound cost estimates.

Our reviews have identified additional factors that have contributed to space cost growth, though less directly. These include consolidations within the defense supplier base for space programs, the diverse array of officials and organizations involved with space programs, short tenures for top leadership and program managers, as well as capacity shortfalls that have constrained DOD's ability to optimize and oversee its space programs. A section at the end of this report lists prior relevant GAO reports.

Program Office Cost Estimates on Space Programs Not Realistic

Our case study analyses found that program office cost estimates—and more specifically, the assumptions upon which those estimates were based—have been unrealistic in eight areas, many of which are interrelated. In some cases, such as assumptions regarding weight growth and the ability to gain leverage from heritage, or legacy, systems, past experiences or contrary data were ignored. In other cases, such as when contractors were given more program management responsibility, as with TSPR, or when growth in the commercial market was predicted, estimators assumed that promises of reduced cost and schedule would be borne out and did not have the benefit of experience to factor into their work. We also identified flawed assumptions that reflected deeper flaws in acquisition strategies or development approaches. For example, five of six programs we reviewed assumed technology would be sufficiently mature when needed, even though the programs began without a complete understanding of how long it would take or how much it would cost to

ensure technologies could work as intended. In four programs, estimators assumed there would be few delays, even though programs were adopting highly aggressive schedules while simultaneously attempting to make ambitious leaps in capability. In four programs, estimators assumed funding would stay constant, even though space and weapon programs frequently experience funding shifts and the Air Force was in the midst of starting a number of costly new space programs to replenish older constellations.

Table 1 highlights major areas where program officials were too optimistic in their assumptions for the six space system acquisitions we examined or where additional evidence showed the estimate was unrealistic. In some cases, programs may have experienced problems related to one of the categories, but we did not have evidence to show the original assumptions were optimistic.

Table 1: Areas Where Program Officials Were Too Optimistic in Their Assumptions

	Space programs affected					
Optimistic assumptions	**AEHF**	**EELV**	**GPS IIF**	**NPOESS**	**SBIRS High**	**WGS**
Industrial base would remain constant and available		X	X	X	X	X
Technology would be mature enough when needed	X		X	X	X	X
TSPR would reduce costs and schedule		X	X	X	X	
Savings would occur from experience on heritage systems	X			X	X	X
No weight growth would occur	X			X	X	X
Funding stream would be stable	X		X	X	X	
An aggressive schedule	X			X	X	X
No growth in requirements	X		X		X	

Source: This table is based on conversations with program and contracting officials and analysis of data they provided. In some cases, we made our own designations based on our prior findings.

- *Assumptions about the space industrial base:* Five programs experienced challenges due to assumptions that were made about the availability and constancy of the industrial base. When cost estimates for some of these programs were developed, cost estimators assumed the programs would gain leverage from the commercial satellite market, which, at the time the programs were initiated, was widely expected to continue to grow. In the EELV program, for instance, the original contracting concept was for the Air Force to piggyback on the anticipated launch demand of the commercial sector. Furthermore, the Air Force assumed that it would benefit financially from competition among commercial vendors. However, the commercial demand never

materialized, and the government was forced to bear the cost burden of maintaining the industrial base in order to maintain launch capability, and assumed savings from competition were never realized. In other cases, programs experienced unanticipated problems resulting from consolidations in the supplier base. For example, contractors took cost-cutting measures that reduced the quality of parts. Contractors also lost key technical personnel as they consolidated development and manufacturing facilities.

- *Assumptions about technology maturity:* In five of the six space system acquisition programs, when cost estimates were developed, program officials and cost estimators assumed that technologies critical to the programs would be mature and available—even though the programs began without a complete understanding of how long or how much it would cost to ensure technologies could work as intended. Invariably, after the programs began and as their development continued, the technology issues ended up being more complex than initially believed. For example, on the NPOESS program, DOD and the Department of Commerce committed funds for the development and production of satellites before the technology was mature—only 1 of 14 critical technologies was mature at program initiation and 1 technology was determined to be less mature after the contractor conducted more verification testing. The program has since been beset by significant cost increases and schedule delays due in part to technical problems, such as the development of key sensors. On the GPS IIF program, the cost estimate was built on the assumption that the military code signal being developed would fit on a single microchip. However, once development started, interface issues arose and the subcontractor had to move to a two-microchip design, which took 8 months to resolve and increased cost to the program.

- *Assumptions about TSPR savings:* Four programs we examined assumed that there would be significant savings associated with adopting the TSPR policy. For example, while TSPR was supposed to relieve contractors of unnecessary oversight, the government assumed that the contractors would still maintain sufficient systems engineering and program management levels by following standard practices to provide oversight of their subcontractors and vendors. However, for a variety of reasons, the savings never materialized. For instance, it was believed that by giving more program management responsibility to contractors and increasing use of commercial equipment, the government could reduce the number of in-house systems engineers—who normally help the government define its requirements by analyzing differences between customer needs and technical possibilities and

analyze progress in development. Ultimately, the reduction in systems engineering staff resulted in cost growth as the programs experienced technical and quality problems that the government was no longer in a position to detect and prevent. Programs also came to realize that commercial parts being relied on were not always suitable for their efforts, and had to resort to costly measures to address this problem. In addition, in implementing TSPR, the government initially entered into contracts that did not allow it to obtain certain cost data from the contractors (e.g., contractor cost data reports and contractor performance reports), even though such data are critical for cost estimators to develop sound cost estimates and important for the government to maintain adequate insight. This was the case for EELV and GPS IIF—both of which have either been restructured or are now planning to issue follow-on contracts that will require cost and pricing data and earned value management data. It should be noted that the Air Force has since recognized problems related to its implementation of TSPR and rejected it as a recommended approach.

- *Assumptions about savings from heritage systems:* Four programs assumed that they would be able to gain leverage from legacy satellite systems and save costs, but as the programs continued and more knowledge was gained about the requirements and the technologies needed to meet the requirements, DOD discovered that the legacy systems could not be relied on, as initially believed, and the savings were not realized. In addition, SBIRS High and WGS, for example, had all planned to gain leverage from commercial satellite development efforts because the government had planned to use portions of these satellites as lessons already learned in order to obtain design savings. However, when hardware and software development advances were slowed as a result of the Internet sector economic downturn, the government had to carry more design and development costs than anticipated.

- *Assumptions about weight growth:* Four case study programs assumed no weight growth, which is among the highest drivers of cost growth for space systems, would occur despite leaps hoped for in technology and experiences in past programs. For example, the SBIRS High program assumed little to no weight growth, but the weight of the satellite spacecraft eventually grew by more than 59 percent, while payload aboard the spacecraft grew by 44 percent. Moreover, with such considerable weight growth, the program could no longer rely on the commercial bus it had originally selected for this acquisition, and instead had to develop a custom satellite bus—a more expensive endeavor.

- *Assumptions about funding:* Space programs frequently experienced funding shifts. Moreover, at the time the Air Force undertook the programs included in our case studies, it was attempting to replenish several older satellite constellations, which put further stress on its total investment in space. Despite this condition, when making estimates on four programs we reviewed, cost estimators assumed that program budgets would remain stable. As the programs progressed through the acquisition cycle, they experienced changes to their funding stream, which created program instability and cost growth due to the stopping and starting of activities. Cost estimators and program officials we interviewed generally agreed that space programs are not often fully funded and that their programs have experienced shifts in funding. However, they could not separate the ultimate effects of funding shifts, since the programs were concurrently experiencing other problems, such as technical or design problems, which were also adding costs, and these funding cuts led to other decisions that had reverberating consequences. For example, in some cases, programs abandoned their original plans to purchase satellites in one procurement in favor of individual orders in an effort to address a funding cut. While this decision enabled the programs to continue in the short term, it had significant long-term consequences on program costs since the price of each satellite substantially increased with the change to individual orders. In previous testimony and reports, we have stressed that DOD could avoid the need to make costly funding shifts by developing an overall investment strategy that would prioritize systems in its space portfolio with an eye toward balancing investments between legacy systems and new programs as well as between science and technology programs and acquisition investments. Such prioritizing would also reduce incentives to produce low estimates.

- *Assumptions about schedules:* Four case study programs assumed that compressed schedules being proposed could be achieved—even though the programs were pursuing ambitious leaps in capability or attempting new approaches, such as using commercial equipment for military purposes. Moreover, in some cases, DOD had data available demonstrating such schedules were not realistic. In one case study program, WGS, the request for proposals specified that the budget available was $750 million for three satellites plus ground control with a schedule constraint of 36 months. On the basis of these requirements, competing contractors were asked to offer maximum capacity, coverage, and connectivity via a contract that would make use of existing commercial practices and technologies. This aggressive schedule was never achieved. Instead, problems due to higher design

complexity and supplier quality issues have caused the WGS schedule to stretch to 78 months for the first expected launch. Historically, the Air Force has required between 55 and 79 months to build satellites similar to WGS, so while the schedule slip is within the expected range, the original 36-month schedule was optimistic and not based on realistic data. For AEHF, the program accelerated its schedule in response to a potential gap in satellite coverage due to the launch failure of the third Milstar satellite. However, when the funding needed to achieve the acceleration was not delivered, the program experienced cost and schedule delays. Again, because these assumptions were made before enough information about the development was available, the assumptions did not hold up, and the programs experienced cost and schedule growth as a result.

- *Assumptions about requirements growth:* Three programs—AEHF, GPS IIF, and SBIRS High—did not assume any requirements growth, even though there was a risk of growth because of the variety of stakeholders involved. High-level requirements for the SBIRS High program—which is being developed to improve missile warning, missile defense, technical intelligence, and battle space characterization—have remained stable since the program began, but prior DOD studies have found that lower-level requirements were in flux and mismanaged until the program was restructured in 1999. According to DOD studies, this was partially due to the TSPR approach, which placed too much responsibility on contractors to negotiate these requirements; the broad customer base for SBIRS; and the ambitious nature of the program to begin with. To illustrate, the SBIRS High program has 19 key performance parameters to satisfy—nearly five times more than the typical DOD space program. In addition, there are over 12,600 requirements that the program must address, and to date, requirements for external users have not been fully defined. DOD has since realized that responsibility for setting lower-level requirements should rest with the government and has taken actions to add more discipline to the requirements-setting process. In another example, GPS IIF was intended to follow on to the GPS II program, yet shortly after the contract was awarded, the government added the requirement for an additional auxiliary payload. This requirement caused the satellite design to be larger than originally planned, and this, in turn, required a larger launch vehicle. Requirements for more robust jamming capability to secure satellite transmissions were also added. Changes from a two-panel to a three-panel solar array design and flexible power were necessary to allow for more power and thermal capability requirements.

Appendix III contains additional detailed examples of instances where program officials were too optimistic in their assumptions for the six space system acquisitions we examined.

Various Incentives and Pressures within DOD Have Contributed to Cost-Estimating Weaknesses

Various incentives and pressures within DOD have contributed to optimistic program office cost estimates for space system acquisitions. As noted earlier, our prior work has found that programs are incentivized to produce optimistic estimates in order to gain approval for funding. At present, DOD does not have a long-term investment strategy that would prioritize its investments and, in turn, reduce pressures associated with competition for funding. A 2003 DOD study on crosscutting problems affecting space acquisitions, known as the Young Panel report, also found that the space acquisition system, in particular, is strongly biased to produce unrealistically low cost estimates throughout the process; advocacy tends to dominate, and a strong motivation exists to minimize program cost estimates, and proposals from competing contractors typically reflected the minimum program content and a price to win. In responding to the Young Panel report as well as our prior reports, DOD officials have not disputed the need for long-term investment planning or that programs are incentivized to produce low estimates.

In conducting this review, we asked cost estimators, program managers, industry officials, and higher-level oversight officials what additional impediments there were to sound cost estimating for space. Their responses included that (1) there is little accountability for producing realistic program office estimates—among both program managers and estimators; (2) estimates produced within program offices are more often used to set budgets than estimates produced by independent estimators; (3) even though space programs experience frequent changes, independent cost estimates are not updated for years at a time; (4) cost-estimator roles and responsibilities are not clear and the cost-estimating function is fragmented; and (5) there are not enough in-house government cost estimators or sufficient data to support their work.

Accountability Is Lacking

It is difficult for cost estimators to be held accountable for the estimates they develop because program decision makers are rarely held accountable for the estimates they use to establish program budgets. This, coupled with the pressure to compete for funding, invites program officials to accept optimistic assumptions and ignore risk and reality when developing cost estimates.

This view was also expressed by many DOD program managers we interviewed for a 2005 review on program management best practices.[8] While many program managers told us that they personally held themselves accountable, many also commented that it is difficult to be accountable when so much is outside their control. During our focus groups, program managers cited sporadic instances when program managers were removed from their positions or forced to retire if programs came in over cost or schedule, but they also cited instances when a program manager was promoted even though the program was experiencing difficulties.

Independent Estimates Not Always Relied Upon

We found examples from our closer examinations of the AEHF, NPOESS, and SBIRS High programs where independent cost estimates were not relied upon by program decision makers. Independent estimates for these space system acquisitions forecasted considerably higher costs and lengthier schedules than program office or service cost estimates. Yet the milestone decision authorities used program office estimates or even lower estimates instead of the independent estimates to establish budgets for their programs. DOD's current space acquisition policy requires that independent cost estimates be prepared by bodies outside the acquisition chain of command, and be considered by program and DOD decision makers. However, the policy does not require that the independent estimates be relied upon to set budgets, only that they be considered at key acquisition decision points.

- *AEHF:* In 2004, AEHF program decision makers relied upon the program office cost estimate rather than the independent estimate developed by the CAIG to support the production decision for the AEHF program—which was more than $2 billion higher. At that time, the AEHF program office estimated the system would cost $6 billion. This was based on the assumption that AEHF would have 10 times more capacity than the predecessor satellite—Milstar—but at half the cost and weight. The CAIG believed that this assumption was overly optimistic given that the AEHF weight had more than doubled since the program began in 1999 to obtain the desired increase in data rate. The latest program office estimate for AEHF is $6.1 billion.

[8] GAO, *Best Practices: Better Support of Weapon System Program Managers Needed to Improve Outcomes*, GAO-06-110 (Washington, D.C.: Nov. 30, 2005).

Table 2: Comparison of 2004 AEHF Program Office and Independent Cost Estimates

	Independent cost estimate			
Program office estimate	**AFCAA**	**CAIG**	**Difference**	**Latest program office estimate**
$6 billion	AFCAA worked jointly with the CAIG to develop the independent estimate	$8.7 billion	44%	$6.1 billion

Source: CAIG and GAO analysis.

Note: Estimates are in fiscal year 2006 dollars.

- *NPOESS:* In 2003, to support the NPOESS development decision, government decision makers relied on the program office's $7.2 billion cost estimate rather than the $8.8 billion independent cost estimate presented by the Air Force Cost Analysis Agency. AFCAA based its estimate on an analysis of historical data from satellite systems, independent software and hardware models, and a risk simulation model using input from 30 independent engineers. The program office relied largely on the contractor's proposal as well as on an unrealistic estimate of what it would cost to integrate the payloads onto the satellite bus. The program has encountered many problems as a result of these optimistic assumptions, and costs have risen to $11.4 billion, based on the latest program office cost estimate.

Table 3: Comparison of 2003 NPOESS Program Office and Independent Cost Estimates

	Independent cost estimate			
Program office estimate	AFCAA	CAIG	Difference	Latest program office estimate
$7.2 billion (based on planned purchase of six satellites)	$8.8 billion		23%	$11.4 billion (based on planned purchase of four satellites)

Source: CAIG and GAO analysis.

Note: Estimates are in fiscal year 2006 dollars. The CAIG was not involved in preparing the 2003 independent cost estimate.

SBIRS High. On the SBIRS High program, the program office and AFCAA predicted cost growth as early as 1996, when the program was initiated. While both estimates at that time were close, approximately $5.6 billion, both were much higher than the contractor's estimated costs. The program was subsequently estimated to cost $3.6 billion by the program office, almost $2 billion less than the original AFCAA or program office estimate. The program office and contractor ultimately assumed savings under TSPR that did not materialize. For instance, with this approach, the SBIRS High contractor used far fewer systems engineers than historical data show have been used for similar programs. To achieve savings, the contractor dropped important systems engineering tasks such as verification and cycling of requirements. The lack of systems engineering resulted in latent design flaws that required more integration and testing when components failed initial testing.

Table 4: Comparison of 1996 SBIRS High Program Office Cost Estimate and Independent Cost Estimate

Program office estimate	AFCAA independent cost estimate	Total program funding	Latest program office estimate
$5.7 billion (based on a planned purchase of five satellites)	$5.6 billion	$3.6 billion	$10.2 billion (based on a planned purchase of three satellites)

Source: AFCAA and Air Force documentation and GAO analysis.

Note: Estimates are in fiscal year 2006 dollars.

We were informed by the CAIG that independent cost estimates are rarely used by the services to develop budgets for acquisition programs. Because CAIG estimates are seldom used and the program offices know this, officials we spoke with believe that there is no incentive on the part of program offices to change their approach to cost estimating. According to a senior CAIG official, program managers often promise to meet the maximum amount of requirements for the least cost. These program officials would rather rely on optimistic cost estimates from the contractors because these estimates most likely align with program objectives.

Appendix IV contains detailed examples of where program and cost-estimating officials disagreed on estimates.

Independent Cost Estimates Not Updated Frequently Enough to Account for Significant Events and Changes

It is possible for space programs to continue for years—as many as 4 years—without updates of independent cost estimates and to see changes within that span of time that have had a substantial impact on cost—including changes in requirements, changes in planned quantities, funding instability, design changes, quality variances resulting from rework, manufacturing or engineering changes, changes in supply chain and logistics management and support, technology-related problems, among others. At times, the only mechanism that forced an updated estimate was DOD policy that the CAIG support the Nunn-McCurdy certification process for programs breaching a certain unit cost threshold.[9] Under this policy,[10] the CAIG provides the Under Secretary with a recommendation concerning the reasonableness of the most recent unit cost estimates by the program.

Because space programs tend to experience such changes after program start, some officials we spoke with in the DOD space cost-estimating community believe that independent cost estimates should be updated more frequently. Opinions differ as to the frequency and phasing of these

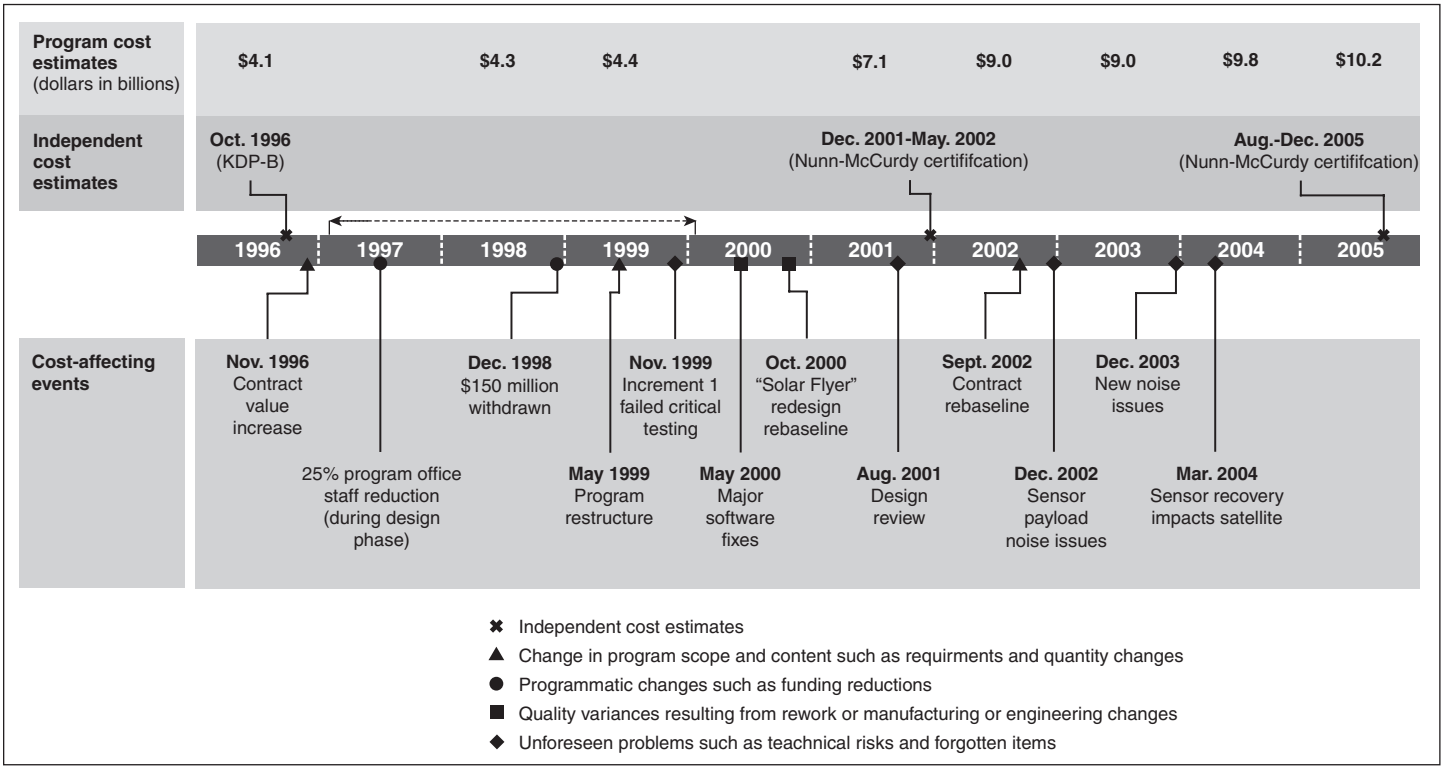
[9] 10 U.S.C. § 2433. This oversight mechanism originated with the Department of Defense Authorization Act, 1982. It was made permanent in the following year's authorization act and has been amended several times. Generally, the law requires DOD to review programs and report (and in some cases submit a certification) to Congress whenever cost growth reaches specified thresholds. The statute is commonly known as Nunn-McCurdy, based on the names of the sponsors of the original legislation.

[10] DOD Directive 5000.04 at ¶ 4.8.

non milestone estimates, assessments, or reviews. A CAIG official suggested updating cost estimates about every 18 to 24 months, while AFCAA officials suggested annually to correspond with the annual budgeting cycle. The current space acquisition policy requires only one independent cost estimate after critical design review, but CAIG officials noted that years can go by between critical design review and program completion, during which time programs have historically experienced substantial changes.

Figure 1 illustrates significant changes that took place on the SBIRS High program both before and after critical design review.

Figure 1: Key Events and Funding Shifts That Occurred between Estimates for SBIRS High



Source: GAO analysis of SBIRS High program data.

Cost-Estimating Roles and Responsibilities Are Unclear

Air Force cost-estimating officials believe that their roles and responsibilities are not clear and that the cost-estimating function is too fragmented. Some also asserted that the cost-estimating function within the space community would be stronger if estimators themselves were

centralized outside the acquisition chain of command so that they would not be biased or pressured by program office leadership to produce optimistic estimates.

In an attempt to make the most efficient use of the limited cost estimate expertise for DOD space system acquisitions, the space acquisition policy called on the CAIG to augment its own staff with cost-estimating personnel drawn from across the community to serve as team members when it developed independent estimates. Members were to include the intelligence community's cost analysis improvement group, the Air Force Cost Analysis Agency, the National Reconnaissance Office (NRO) Cost Group, the Office of the Deputy Assistant Secretary of the Army for Cost and Economics, the Naval Center for Cost Analysis, the cost-estimating organizations of the Air Force Space Command, Air Force Space and Missile Systems Center, and the Space and Naval Warfare Systems Command.

At this time, however, there are still significant disconnects in views about roles and responsibilities. Officials who reside in the acquisition chain of command—the Air Force Space and Missile Systems Center—believe that because the program executive officer and the program managers are responsible for executing the programs, they are also solely responsible for the cost estimates for the program. On the other hand, Air Force cost estimators outside the acquisition chain of command—the Air Force Cost Analysis Agency—believe they also hold some responsibility to ensure the quality and consistency of cost estimates and to produce independent cost estimates for consideration by Air Force decision makers. However, according to officials within the Space and Missile Systems Center's (SMC) cost-estimating group and AFCAA, the SMC cost-estimating group sees no role for AFCAA in developing program or Air Force cost estimates and has rejected assistance from AFCAA. According to Air Force officials, until a clearer distinction of roles and responsibilities is defined by Air Force leadership, issues of conflicting policy interpretation and implementation will remain. It is also possible that these disconnects have been exacerbated by the perception that these two communities are competing for responsibility.

In addition, according to a senior CAIG official, the collaborative process for developing independent estimates has not been achieved as envisioned—principally because those who should be involved have not seen their involvement as a priority, and those who have been involved have required a lot of extra training to be able to make valuable contributions. Moreover, because the various cost-estimating

organizations each have different customers, agendas, and approaches to developing cost estimates, these differences have made it difficult for them to work as a cohesive team.

Cost-Estimating Resources Are Considered Inadequate

Air Force space cost-estimating organizations and program offices believe that cost-estimating resources are inadequate to do a good job of accurately predicting costs. They believe that their cost-estimating resources have atrophied over the years because of previous downsizing of the workforce, making resources such as staff and data inadequate.

As noted earlier, there was a belief within the government that cost savings could be achieved under acquisition reform initiatives by reducing technical staff, including cost estimators, since the government would be relying more on commercial-based solutions to achieve desired capabilities. According to one Air Force cost-estimating official we spoke with, this led to a decline in the number of Air Force cost estimators from 680 to 280. High-grade positions and specialty cost-estimating job codes were eliminated, abolishing an official cost-estimating career path, and subordinating cost estimating as an additional duty. In the process, according to this same Air Force official, many military and civilian cost-estimating personnel left the cost-estimating field, and the Air Force lost some of its best and brightest cost estimators.

Information we obtained from space program offices and cost-estimating organizations is consistent with the assertion of a lack of requisite resources. Eight of 13 cost-estimating organizations and program offices we informally surveyed believe the number of cost estimators is inadequate. Furthermore, some of these same organizations believe that cost estimation is not a respected career field within the Air Force, and more specifically, that Air Force cost estimators are not encouraged, nor do they have opportunities for promotion or advancement. Regarding the recognition and career paths for cost estimators, our data showed that only 3 of 12 organizations agreed that previous cost estimators had moved on to positions of equal or higher responsibility. Further, only 4 of 12 agreed that people ask to become cost estimators.

The belief that cost-estimating skills have been depleted has been echoed in other DOD and GAO studies. According to the Young Panel report, government capabilities to lead and manage the acquisition process have seriously eroded, in part because of actions taken in the acquisition reform environment of the 1990s. This has extended to cost estimating. During our 2005 review of program management, we surveyed DOD's major

weapon system program managers and interviewed program executive officers who similarly pointed to critical skill shortages for staff that support them, including cost estimators. Other skill gaps identified included systems engineering, program management, and software development. We continue to observe these deficiencies in our more recent reviews of the space acquisition workforce.[11]

Because of the decline in in-house cost-estimating resources, space program offices and Air Force cost-estimating organizations are now more dependent on support contractors. Ten of 13 cost-estimating organizations and program offices have more contractor personnel preparing cost estimates than government personnel. At 11 space program offices, contractors account for 64 percent of cost-estimating personnel. Support contractor personnel generally prepare cost estimates, while government personnel provide oversight, guidance, and review of the cost-estimating work. By contrast, the CAIG had made a determination that cost estimating is too important of a function to place in the hands of support contractors, and assigns only government personnel to develop cost estimates.

Reliance on support contractors raises questions from the cost-estimating community about whether numbers and qualifications of government personnel are sufficient to provide oversight of and insight into contractor cost estimates. A senior CAIG official involved with estimating for space acquisition programs, for example, suggested that reliance on support contractors is a problem if the government cannot evaluate how good a cost estimate is or lacks the ability to track it. Two studies have also raised the concern that relying on support contractors makes it more difficult to retain institutional knowledge and instill accountability. Further, in the most recent defense authorization act, Congress is requiring DOD to make it a goal that within 5 years certain critical acquisition functions, including cost estimating, be performed by properly qualified DOD employees, and that in developing a comprehensive strategy for supporting the program

[11] GAO, *Defense Space Activities: Management Actions Are Needed to Better Identify, Track, and Train Air Force Space Personnel*, GAO-06-908 (Washington, D.C.: Sept. 21, 2006), and *Defense Acquisitions: DOD Needs to Establish an Implementing Directive to Publish Information and Take Actions to Improve DOD Information on Critical Acquisition Positions*, GAO-06-987R (Washington, D.C.: Sept. 8, 2006).

manager role, DOD address improved resources and support such as cost-estimating expertise.[12]

A second resource gap hampering cost estimating is the lack of reliable technical source data. Officials we spoke with believe that cost estimation data and databases from which to base cost estimates are incomplete, insufficient, and outdated. They cite a lack of reliable historical and current cost, technical, and programmatic data and expressed concerns that available cost, schedule, technical, and risk data are not similar to the systems they are developing cost estimates for. In addition, some expressed concerns that relevant classified and proprietary commercial data may exist but are not usually available to the cost-estimating community working on unclassified programs. Some believe that Air Force cost estimators need to be able to use all relevant data, including those contained in NRO cost databases, since the agency builds highly complex, classified satellites in comparable time and at comparable costs per pound.

Successful Organization Approaches That Better Support Cost Estimating

Over the past decade, GAO has examined successful organizations in the commercial sector to identify best practices that can be applied to weapon system acquisitions. This work has identified a number of practices that better support cost estimating than DOD does. For instance, unlike most space programs we have reviewed, the successful organizations we have studied extensively researched and defined requirements before program start to ensure that they are achievable, given available resources. They do not define requirements after starting programs. They also ensure technologies are mature, that is, proven to work as intended, and assign more ambitious efforts to corporate research departments until they are ready to be added to future increments. In addition, these organizations use systems engineering to close gaps between resources and requirements before launching the development process. Taken together, these practices help ensure that there is little guessing in how long or how many dollars it will take to achieve an intended capability. Moreover, within the organizations we studied, decisions to start programs are made through long-term strategic planning and prioritizing. As a result, competition for funding is minimized, and programs themselves do not have incentives to present low estimates.

[12] John Warner National Defense Authorization Act for Fiscal Year 2007, Pub. L. No. 109-364 §§ 820, 853 (2006).

The successful organizations we have studied have taken additional steps to ensure cost estimates are complete and accurate that DOD has not. For instance, they hold program managers accountable for their estimates and require program managers to stay with a project to its end. At the same time, they develop common templates and tools to support data gathering and analysis and maintain databases of historical cost, schedule, quality, test, and performance data. Cost estimates themselves are continually monitored and regularly updated through a series of numerous gates or milestone decisions that demand programs assess readiness and remaining risk within key sectors of the program as well as overall cost and schedule issues.

Senior leaders within these organizations also actively encourage program managers to share bad news about their programs and spend a great deal of time breaking down stovepipes and other barriers to sharing information. More important, they commit to fully funding programs and adhere to those commitments. Commonly, the organizations we studied have centralized cost estimators and other technical and business experts so that there is more effective deployment of technical and business skills while at the same time ensuring some measure of independence. Within DOD, the CAIG is a good example of this. Its cost estimates are produced by civilian government personnel (the sole military space cost estimating position will convert to a civilian position later on this year when the military cost estimator retires), to ensure long-term institutional knowledge and limit the effects of staff turnover that commonly occur with military personnel. Although the CAIG uses support contractors for conducting studies, it does not allow cost estimates to be developed by contractors. The CAIG takes this approach because it considers cost estimating to be a core function and therefore too important to contract out. The Naval Air Systems Command's Cost Analysis Division is also considered a model by some in the cost-estimating community because of its organizational structure and leadership support. It is a centralized cost department that provides support to multiple program offices. The department is headed by a senior executive-level manager, and various branches within the department are headed by GS-15-level managers. Analysts are somewhat independent of the program offices, as their supervisors are within the engineering department. This cost department has strong support from its leadership, and this support has helped it hire the number of analysts and receive the resources it needs. However, another official pointed out that this cost department is not completely independent from the acquisition chain of command, since it receives funding from the program offices to conduct the cost estimates.

GAO has made recommendations to DOD to adopt best practices we have identified that would strengthen program management DOD-wide. Congress also recently directed DOD to develop a strategy to enhance program manager empowerment and accountability, agreeing with GAO's assessment that DOD has consistently failed to give program managers the authority that they need to successfully execute acquisition programs and, as a result, is unable to hold them accountable.[13] GAO has also made recommendations to the Air Force to better position its space programs for success. In response, the Air Force has restructured its Transformational Satellite Communications System (TSAT) to ensure that the program incorporates technologies that have been proven to work as intended, and it has deferred more ambitious efforts to the science and technology community. It has committed to do the same on other programs. If effectively implemented, such actions would, in turn, significantly enhance the ability of independent estimators to forecast costs. However, we have testified that DOD faces a number of challenges and impediments in its effort to instill this approach. It needs significant shifts in thinking about how space systems should be developed, changes in incentives and perceptions; and further policy and process changes. And such changes will need to be made within a larger acquisition environment that still encourages a competition for funding and consequently pressures programs to view success as the ability to secure the next installment rather than the end goal of delivering the capabilities when and as promised.

The Air Force has also been taking actions to make specific improvements to cost estimating for space programs. In the case of TSAT, program officials said they are updating the program's planning cost estimate on an annual basis. Furthermore, according to one CAIG official, some program offices have recently been using the CAIG's independent cost estimates. Both the SBIRS High and NPOESS program offices are developing their budgets based on the CAIG independent estimates that support the certification process for the programs' most recent Nunn-McCurdy breaches. Further, DOD and Air Force cost estimators we spoke to recognize that amendments made to the Nunn-McCurdy law by the 2006 Defense Authorization Act may increase realism in establishing initial cost estimates. As part of the revisions, DOD is barred from changing its

[13] John Warner National Defense Authorization Act for Fiscal Year 2007, Pub. L. No. 109-364, § 853 (2006), and accompanying conference report, H.R. Rep. No. 109-702, pages 784-785.

original baseline cost estimate for a program until after it has breached certain Nunn-McCurdy thresholds that require a certification and assessment of the program, and DOD must report the baseline changes to Congress.

The Air Force has also committed to strengthening its cost-estimating capabilities in terms of people, methodologies, and tools. For instance, 50 new cost estimators have recently been authorized to the AFCAA, some of whom may be detailed to the Space and Missile Systems Center. Finally, key players within the DOD space cost-estimating community are meeting on a regular basis to discuss issues, review recent findings from GAO and other groups, and explore lessons learned and potential ideas for improvement.

Conclusions

Costs for DOD space acquisitions over the past several decades have consistently been underestimated—sometimes by billions of dollars. For the most part, this has not been caused by poor cost estimating itself, but rather the tendency to start programs before knowing whether requirements can be achieved within available resources. In fact, with so many unknowns about what could be achieved, how, and when, even the most rigorous independent cost estimate could have been off by a significant margin. Nevertheless, in the past, the Air Force has exacerbated acquisition problems by not relying on independent cost estimates and failing to encourage more realism in program planning and budgeting. Moreover, even after the Air Force embraced independent cost estimating in its acquisition policy for space, it did not facilitate better estimating by according the cost-estimating community with the organizational clout, support, and guidance the Air Force believes are needed to ensure the community's analyses are used. On a positive note, the Air Force has committed to addressing some of the root causes behind cost growth, principally by accumulating more knowledge about technologies before starting new programs. Though adopting this approach will be challenging without larger DOD acquisition, funding, and requirement-setting reforms, the Air Force can facilitate better planning and funding approaches by aligning resources and policy to support improved cost-estimating capability and by following through on its commitment to use independent estimates.

Recommendations for Executive Action

We recommend that the Secretary of Defense direct the Under Secretary of Defense for Acquisition, Technology and Logistics or the Secretary of the Air Force, as appropriate, to take the following actions:

1. To increase accountability and transparency of decisions in space programs where an independent estimate produced by the CAIG or AFCAA is not chosen, require officials involved in milestone decisions to document and justify the reasons for their choice and the differences between the program cost estimate and the independent cost estimate.

2. To better ensure investment decisions for space programs are knowledge-based, instill processes and tools necessary to ensure lessons learned are incorporated into future estimates. This could include

   - conducting postmortem reviews of past space program cost estimates (program office and independent cost estimates) to measure cost-estimating effectiveness and to track and record cost-estimating mistakes;
   - developing a centralized cost-estimating database that provides realistic and credible data to cost estimators;
   - establishing protocols by which cost estimators working with the National Reconnaissance Office can share data with the DOD space cost-estimating community while still maintaining appropriate security over classified data; and
   - ensuring estimates are updated as major events occur within a program that could have a material impact on cost, such as budget reductions, integration problems, hardware/software quality problems, and so forth.

3. To optimize analysis and collaboration within the space cost-estimating community, clearly articulate the roles and responsibilities of the various Air Force cost-estimating organizations, and ensure that space system cost estimators are organized so that the Air Force can gain the most from their knowledge and expertise. In taking these actions for programs for which no independent estimate is developed by the CAIG, consider assigning AFCAA the responsibility for the development of independent cost estimates for space system acquisitions, since it is outside of the acquisition chain of command and therefore likely to be unbiased and not pressured to produce optimistic estimates.

Agency Comments and Our Evaluation

DOD provided us with written comments on a draft of this report. DOD concurred with the overall findings in our report and provided technical comments, which have been incorporated where appropriate. DOD also concurred with two of our recommendations and partially concurred with one.

DOD concurred with our recommendation to instill processes and tools necessary to ensure lessons learned are incorporated into future estimates. DOD stated it was already taking actions to address our recommendations. For example, the CAIG has established a process whereby key members of the national security space cost analysis community meet to discuss and evaluate outcomes following ACAT I space program milestone reviews or key decision point Defense Acquisition Board-level reviews, to provide visibility to other members of the community on how the CAIG approaches independent cost estimate development and to give the community an opportunity to provide feedback to the CAIG on how to improve its processes. DOD stated that the CAIG will work in the future to incorporate peer reviews of the program office estimates within this existing framework. DOD also concurred with our recommendation to develop a centralized cost-estimating database, and stated that several groups within the space cost-estimating community have been working to develop a database of historical space program costs available to the community as a whole, and has also reestablished a common space program work breakdown structure that supports the various estimating methodologies employed by the space cost community. Through the common database development process, the community is working to make historical program cost data as widely available as possible. DOD also agreed with our recommendation to update cost estimates as major events occur within a program, as long as they are program and program phase dependent. Finally, DOD concurred with our recommendation to clearly articulate the roles and responsibilities of the various cost-estimating organizations. DOD stated that the Air Force is currently updating its policy directive to further clarify the roles and responsibilities of the space cost analysis organizations to optimize analysis and collaborations, thus making the best use of the limited number of qualified and experienced space program cost analysts. We agree that these actions are steps in the right direction and that they will strengthen cost-estimating capabilities and improve space program cost estimates.

DOD partially concurred with our recommendation to require officials involved in milestone decisions to document and justify the reasons for their cost estimate choice and the differences between the program cost

estimate and the independent cost estimate. In commenting on this recommendation, DOD stated that the complex decision to determine which cost figure to use as basis for funding and to evaluate future program performance must weigh many competing factors that are often qualitative in nature. It further stated that the decision is the milestone decision authority's alone, and that documenting the explicit justification will reduce the milestone decision authority's future decision-making flexibility. We do not see how documenting the explicit justification will significantly reduce the milestone decision authority's future decision-making flexibility. While we recognize the value of decision-making flexibility and the role that judgment must play in such decisions, we also believe that the basis for the decisions should withstand review, particularly after the person who made the decision has left office. We also believe that the greater transparency of cost-estimating decisions that a documented justification provides is needed, particularly in light of the poor foundation of choices made in the past on space programs.

We are sending copies of this report to interested congressional committees and the Secretaries of Defense and the Air Force. We will also provide copies to others on request. In addition, this report will be available at no charge on the GAO Web site at http://www.gao.gov.

If you have any questions about this report or need additional information, please call me at (202) 512-4841 (chaplainc@gao.gov). Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made major contributions to this report are listed in appendix VI.

Cristina T. Chaplain
Acting Director, Acquisition and Sourcing Management

Appendix I: Scope and Methodology

The Chairman and the Ranking Member, Subcommittee on Strategic Forces, House Committee on Armed Services, requested that we examine (1) in what areas space system acquisitions cost estimates have been unrealistic and (2) what incentives and pressures have contributed to the quality and usefulness of cost estimates for space system acquisitions.

To determine whether cost estimates for space system acquisitions have been realistic, we used a case study methodology. We selected six ongoing Air Force space system acquisitions. We selected these acquisitions because they were far enough along in their acquisition cycles for us to be able to observe changes in the programs since their initial cost estimates were developed. The six space system acquisitions are the Advanced Extremely High Frequency Satellites, the Evolved Expendable Launch Vehicle, the Global Positioning System IIF, the National Polar-orbiting Operational Environmental Satellite System, the Space Based Infrared System High, and the Wideband Gapfiller Satellites. For each of the case studies, we met with the program office representatives at the Air Force's Space and Missile Systems Center and at the program's prime contractors. We also obtained program cost and other program documentation to determine how the cost estimates were formulated and on what basis they were formulated.

To determine what incentives and pressures contributed to the quality and usefulness of cost estimates for space system acquisitions, we examined Department of Defense (DOD) and Air Force policies for developing and updating cost estimates for space programs. We also used a data collection instrument to obtain information on cost-estimating practices and resources within the Air Force Cost Analysis Agency, at the Space and Missile Systems Center, and at the space program offices. We conducted interviews with the Office of the Secretary of Defense's Cost Analysis Improvement Group, the Air Force Cost Analysis Agency, and the Air Force Space and Missile Systems Center's Cost Center. On the basis of the results of the data collection instruments and interviews, we obtained information on the organizational alignment of cost-estimating organizations, including roles and responsibilities, as well as concerns over the current cost-estimating policies and practices.

We also relied on our previous best practice studies, which have examined pressures and incentives affecting space system acquisition programs, the optimal levels of knowledge needed to successfully execute programs, and complementary management practices and processes that have helped commercial and DOD programs to reduce costs and cycle time. Moreover, we reviewed studies from the Defense Science Board, the DOD Inspector

General, IBM, and others on space system acquisition and cost-estimating issues.

Finally, we discussed the results of our work and our observations with an expert panel made up of representatives from the DOD space cost-estimating community.

We conducted our review between August 2005 and October 2006 in accordance with generally accepted government auditing standards.

Appendix II: DOD Acquisition Categories for Major Defense Acquisition Programs

An acquisition program is categorized based on dollar value and milestone decision authority special interest. Table 5 contains the description and decision authority for acquisition categories ID and IC.

Table 5: DOD Acquisition Categories and Decision Authorities

Acquisition category (ACAT)	Dollar value	Milestone decision authority
ACAT ID For designated major defense acquisition programs (special interest based on technological complexity, congressional interest, large commitment of resources, critical role in achieving a capability, or a joint program)	Research, development, test, and evaluation > $365 million Procurement > $2.19 billion	Under Secretary of Defense for Acquisition, Technology and Logistics
ACAT IC For major defense acquisition programs not designated as ACAT ID	Research, development, test, and evaluation > $365 million Procurement > $2.19 billion	Head of DOD component or, if delegated, DOD component or service acquisition executive

Source: DOD Instruction 5000.2, Enclosure 2, which also lists other acquisition categories.

Note: Dollar values are fiscal year 2000 constant dollars.

Appendix III: Examples of Where Program Officials Were Too Optimistic in Their Assumptions

Table 6 highlights major areas where program officials were too optimistic in their assumptions for the six space system acquisitions we examined—the Advanced Extremely High Frequency (AEHF) Satellites, the Evolved Expendable Launch Vehicle (EELV), the Global Positioning System (GPS) IIF, the National Polar-orbiting Operational Environmental Satellite System (NPOESS), the Space Based Infrared System (SBIRS) High, and the Wideband Gapfiller Satellites (WGS).

Table 6: Examples of Optimistic Assumptions

Space program affected	Examples
Assumed industrial base would remain constant and available	
EELV	The original contracting concept was for the Air Force to piggyback on the launch demand anticipated to be generated by the commercial sector. However, the commercial demand never materialized, and the government had to take on an additional cost burden. In addition, the cost for launch services increased because fixed infrastructure costs are being spread over 15 launches a year instead of the original expectation of 75 launches a year.
GPS IIF	A deteriorating manufacturing base of contractors and subcontractors caused the prime contractor to move the design team from Seal Beach, California, to Anaheim, California, in 2001. Additional moves occurred as the prime contractor consolidated development facilities to remain competitive. For each move, the prime contractor lost valuable workers, causing inefficiencies in the program. In addition, the contractor took additional cost-cutting measures that reduced quality.
NPOESS	A long production phase on this program increases the probability for parts obsolescence. Over 70 percent of the value added to the program is from the supply base, and some critical parts that are unique to the program are produced by relatively small companies. In addition, workers required to have specialized skills must be United States citizens to obtain security clearances. The labor pool has to produce these specialized skills because degree programs currently do not produce them.
SBIRS High	Consolidation within the supplier base has adversely affected the program. When suppliers merged, costs increased for supplier technical assistance, product rework, and hardware qualifications. In addition, unforeseen costs resulted when production processes and materials were changed and facilities and personnel were relocated.
WGS	At the time of contract award, the satellite industry was flourishing with commercial satellite orders, and the contractor anticipated a large market. However, when the installation of optical fiber communication lines became widespread, many of the commercial initiatives involving proposed space systems did not materialize. The government had planned to gain leverage from the design work of commercial contractors but ended up having to pay for design efforts. In addition, because of the reduction of the number of contracts awarded, small subcontractors started to consolidate. Specialized parts became obsolete, and the Air Force was no longer considered a high-priority customer.
Assumed technology would be mature enough when needed	
AEHF	AEHF faced several technology maturity problems including developing a digital processing system that would support 10 times the capacity of Milstar medium data rate without self-interference, and using phased array antennas at extremely high frequencies, which had never been done before. In addition, the change from a physical to an electronic process for crypto re-keys was not expected at the start of the AEHF. The predecessor program to AEHF was Milstar, which required approximately 2,400 crypto re-keys per month, which could be done physically. Regarding AEHF proposed capabilities, the number of crypto re-keys is approximately 100,000, which is too large for a physical process and must be done electronically. Changing the way the re-keys were done called for a revolutionary change in the process and led to unexpected cost and schedule growth.

Space program affected	Examples
GPS IIF	The cost estimate was built on the assumption that the military code being developed in the program would fit on one chip. However, once development started, there were interface issues, and the subcontractor had to move to a two-chip design, which added cost growth to the program. In addition, the problem took 8 months to solve.
NPOESS	DOD and the Department of Commerce committed funds for the development and production of the satellites before the design was proven and before the technology was mature. At program initiation, only 1 of 14 critical technologies was mature, and some technology levels have been assessed downward. For example, the 1394 Bus Technology Readiness Level (TRL) was changed from 5 to 4 after the contractor added more verification testing.
SBIRS High	In 2003, GAO reported that three critical technologies—the infrared sensor, thermal management, and onboard processor—were now mature. When the program began, in 1996, none of its critical technologies was mature.
WGS	The X-band phased array antennas and the array power chips were the most difficult technologies to mature, because these state-of-the-art elements generated too much heat, which is very difficult to remove in outer space, so they had to be redesigned.
Assumed Total System Performance Responsibility (TSPR) would reduce costs and schedule	
EELV	The EELV program office entered into a TSPR contract that does not require the contractor to deliver cost or earned value management data. The program office stated that TSPR gave too many responsibilities to the contractor and not enough to the government.
GPS IIF	The contract that was awarded during acquisition reform efforts of the late 1990s adopted the TSPR approach. Under TSPR, there was limited oversight of the contractor, and this contributed to relaxed specifications and inspections on commercial practices, loss of quality in the manufacturing process, and poor-quality parts that caused test failures, unexpected redesigns, and the late delivery of parts.
NPOESS	The NPOESS prime contractor has a Shared System Performance Responsibility (SSPR), which was an outgrowth of TSPR. The SSPR arrangement relegates the government's role as a participant in contractor Integrated Product Team meetings. In addition, the program is managed by officials from three separate government agencies. DOD and Department of Commerce share the cost of funding the development of NPOESS, while NASA provides funding for specific technologies and studies. Difficulties have arisen with the tri-service approach to managing NPOESS, including ensuring NPOESS follows DOD's acquisition process, but Commerce, which has control over the program, has no authority over the DOD process; each agency is driven by different program objectives (i.e., military, civilian, science); and NASA shares equally in managing the program even though it provides no funding for the development.
SBIRS High	When the original contract was awarded, acquisition reform efforts were being implemented and called for the use of commercial practices instead of government standards. In order to achieve cost savings, the SBIRS program office reduced critical up-front systems engineering design practices and follow-on quality assurance inspections based on the expectation that the contractor would perform these activities with no government oversight. The prime contractor also held the same requirements for its subcontractors as a way to keep costs down. This lack of oversight resulted in difficulties in determining the root causes when components began to fail during testing. For example, there have been latent defects that required extensive corrective action and associated cost growth with the software redesign, single board computer halts, payload reference bench rework, payload electromagnetic interference, software configuration issues, propulsion solder issues, and telescope foreign object damage. In addition, the contractor had responsibility to coordinate different agency needs, a responsibility that proved to be difficult when trying to resolve hardware interface issues.

Space program affected	Examples
Assumed savings from heritage systems	
AEHF	The program office cost estimators relied on data from heritage systems to estimate AEHF nonrecurring costs. The Cost Analysis Improvement Group (CAIG) believed the estimates based on heritage data were subjectively derived and therefore susceptible to bias. For example, AEHF program officials assumed that the nulling antennas would have the same performance as those on Milstar, requiring little if any development. In fact, because of parts obsolescence, personnel turnover, and other issues, the entire antenna had to be redesigned at nearly the same cost as the first one. There were similar beliefs that legacy processing technology could be used, which turned out to not be possible. Further, almost all of the payload software had to be rewritten to support the new hardware. As a result, there was much less technology transfer from Milstar II to AEHF, even though the contractor was the same.
NPOESS	NPOESS payload development proposals relied heavily on leveraging heritage satellite instrument technology development. The prime contractor and the program office agreed there was too much optimism regarding heritage sensor reuse. For example, the Visible Infrared Radiometer Suite (VIIRS) is more powerful and complex and will weigh 20 percent more than the heritage sensor that was used to base the estimate. In addition, the Conical Microwave Imager Sounder (CMIS) is much more complex than the heritage sensor, which took more than 8 years to develop. The program office estimated a 4-year development schedule for CMIS. The latest cost estimate for CMIS is now approximately five times the initial estimate.
SBIRS High	The original estimate for nonrecurring engineering was significantly underestimated based on actual experience in legacy sensor development and assumed software reuse. As a result, nonrecurring costs should have been two to three times higher according to historical data and independent cost estimators.
WGS	Originally, the contractor planned to gain leverage from a commercial satellite development effort—using the same bus and phased array antenna. The commercial satellite development effort did not materialize, leaving DOD to pay for infrastructure and hardware design costs. This caused WGS costs to increase and the schedule to slip.
Assumed no weight growth would occur	
AEHF	When the cost estimate was initially developed, satellite payload weight was assumed to be constant by the program office. When updating its independent cost estimate in 2004, the CAIG found that the payload weight more than doubled between the start of development and critical design review. Weight increased because of the addition of phased array antennas, an antenna modification, and other requirements.
NPOESS	The CMIS sensor weight has almost doubled since the preliminary design review. As a result, engineering change proposals were issued to modify the spacecraft to accept the higher payload weight.
SBIRS High	Weight growth has occurred in the spacecraft and payload. The spacecraft has experienced weight growth of about 59 percent because of the need to lengthen and stiffen the structure, add a solar shield to block sunlight from the payload, and add missing wire and harnessing. The geosynchronous earth orbit (GEO) payload has experienced nearly a 44 percent weight growth because of integration hardware, pointing, and control assembly.
WGS	Problems with solar panel concentrators overheating caused a solar panel redesign that led to additional weight growth in the spacecraft bus.
Assumed funding stream would be sufficient and remain stable	
AEHF	The AEHF program sustained a $100 million fiscal year 2002 funding cut. The program office reported that the funding cut would result in a 6-month launch delay to the first three satellites and a delay in meeting initial operational capability. The program had rapidly staffed personnel to support a warfighter need. The funding cut resulted in contractor program reductions to fit within the revised fiscal year 2002 budget. In addition, DOD made a decision to shift the acquisition strategy from buying five satellites at one time to buying three satellites as individual buys, which also caused costs to rise.

Space program affected	Examples
GPS IIF	The Operational Control Segment portion of the GPS IIF program received a $37.7 million funding cut in fiscal year 2005. Because of the funding cut, the program delayed some of the software efforts and reduced some software requirements.
NPOESS	Between fiscal years 2004 and 2005, DOD reduced funding for the program by about $65 million. However, funding was reduced $130 million since the Department of Commerce contributes no more funding towards the program than DOD. The program office determined that the funding cut resulted in satellite launch delays ranging from 5 to 26 months and a cost increase of $391.2 million.
SBIRS High	A funding cut in 1998-1999 because of higher budget priorities caused a reduction in the systems engineering staff and contributed to a 2-year delay of the geosynchronous earth orbit satellites. This cut caused work activities to continually stop and restart and drove the need for interim solutions that resulted in program instability and cost growth. It also led to a breach of the acquisition program baseline in 2001, resulting in a change in the procurement strategy from a single buy of five satellites to two separate buys—one for two satellites and the other for three satellites. Independent cost estimators calculated that costs would double as a result of the change in procurement strategy.
Assumed an aggressive schedule	
AEHF	The first launch was originally scheduled for June 2006, but in response to a potential gap in satellite coverage due to the launch failure of the third Milstar satellite, DOD accelerated the schedule by 18 months, aiming for a first launch in December 2004. An unsolicited contractor proposal stated that it could meet the accelerated date, even though all the requirements for AEHF were not fully determined. As a result, the program office knew that the proposed schedule was overly optimistic, but the decision was made at high levels in DOD to award the contract. However, DOD did not commit the funding to support the activities and manpower needed to design and build the satellites more quickly. Funding issues further hampered development efforts and increased schedule delays and contributed to cost increases.
NPOESS	When the estimate was developed, NPOESS was expected to be heavier, require more power, and have over twice as many sensors than heritage satellites. Yet the program office estimated that the satellites would be developed, integrated, and tested in less time than heritage satellites. Independent cost estimators highlighted to the NPOESS program office that the proposed integration schedule was unrealistic when compared to historical satellite programs. Later, the CAIG cautioned the program office that not only was the system integration assembly and test schedule unrealistic, but the assumptions used to develop the estimate were not credible.
SBIRS High	The schedule proposed in 1996 did not allow sufficient time for geosynchronous earth orbit system integration and did not anticipate program design and workmanship flaws, which eventually cost the program considerable delays. In addition, the schedule was optimistic in regard to ground software productivity, and time needed to calibrate and assess the health of the satellite. There has been almost a 3-year delay in the delivery of the highly elliptical orbit (HEO) sensors and a 6-year delay in the launch of the first GEO satellite.
WGS	The request for proposals specified that the budget available was $750 million for three satellites and the ground control system to be delivered within 36 months. On the basis of these requirements, competing contractors were asked to offer maximum capacity, coverage, and connectivity through a contract that would make use of existing commercial practices and technologies. However, higher design complexity and supplier quality issues caused the WGS schedule to stretch to 78 months for the first expected launch. Historically, DOD experienced between 55 and 79 months to develop satellites similar to WGS, so while DOD's experience is within the expected range, the original 36-month schedule was unrealistic.

Space program affected	Examples
Assumed no growth in requirements	
AEHF	DOD awarded the contract for AEHF before the requirements were fully established to fill the gap left by the Milstar launch failure. As a result, DOD frequently and substantially altered requirements in the early phases of the program and changed the system design. For example, a new requirement increased the need for anti-jamming protection, which led to a cost increase of $100 million. In addition, new requirements related to training, support, and maintainability led to a cost increase of $90 million.
GPS IIF	GPS IIF was intended to follow on the GPS II program, yet shortly after the contract was awarded, the government added the requirement for an additional auxiliary payload. This requirement caused the satellite design to be larger than originally planned and, in turn, required a larger launch vehicle. Requirements for more robust jamming capability to secure satellite transmissions were also added. Changes from a two-panel to a three-panel solar array design and flexible power were necessary to allow for more power and thermal capability requirements.
SBIRS High	DOD is developing SBIRS High to improve missile warning, missile defense, technical intelligence, and battle-space characterization. As such, SBIRS has many customers, including the Air Force, Army, missile defense, and other agencies, each of which has its own requirements. This has resulted in complications in developing SBIRS, due to the fact that there are 19 key performance parameters to satisfy, which are about five times more than the typical DOD program. In addition, there are over 12,600 requirements for the program to address, and to date, requirements from external users have not been fully defined. Under the TSPR arrangement, the contractor was responsible for coordinating these requirements. This effort was challenging and, according to a DOD official, one better suited for the government because all agencies were to agree on requirements. The SBIRS contractor encountered numerous problems when trying to resolve the interface issues among the various agencies. Moreover, the development of interface control documents required different certification requirements for each agency, and the SBIRS contractor had limited systems engineers to handle the workload. This lack of staff resulted in many requirements not flowing down, which led to problems later on.

Source: This table is based on conversations with program and contracting officials and analysis of data they provided. In some cases, we made our own designations based on our prior findings.

Appendix IV: Examples Where Independent Cost Estimates Were Not Relied Upon

We found examples from our close examinations of the AEHF, NPOESS, and SBIRS High programs where independent cost estimates were not relied upon by program decision makers. Independent estimates for these space system acquisitions forecasted higher costs and lengthier schedules than program office or service cost estimates. This appendix provides detailed information on the differences between the program office cost estimates and the independent cost estimates for the AEHF, NPOESS, and SBIRS High programs.

AEHF

In 2004, AEHF program decision makers relied upon the program office cost estimate rather than the independent estimate developed by the CAIG to support the production decision for the AEHF program. At that time, the AEHF program office estimated the system would cost about $6 billion. This was based on the assumption that AEHF would have 10 times more capacity than the predecessor satellite—Milstar—but at half the cost and weight. However, the CAIG concluded that the program could not deliver more data capacity at half of the weight given the state of technology at that time. In fact, the CAIG believed that in order to get the desired increase in data rate, the weight would have to increase proportionally. As a result, the CAIG estimated that AEHF would cost $8.7 billion, and predicted a $2.7 billion cost overrun for the AEHF program. Table 7 displays the differences between the program office and CAIG cost estimates.

Table 7: Comparison of 2004 AEHF Program Office and Independent Cost Estimates

Millions of fiscal year 2006 dollars

	Independent cost estimate			
Program office estimate	AFCAA	CAIG	Difference	Latest program office estimate
$6,015	[a]	$8,688	44%	$6,132

Source: CAIG and GAO analysis.

[a]AFCAA worked jointly with the CAIG to develop the independent estimate.

The CAIG relied on weight data from historical satellites to estimate the cost of AEHF because it considers weight to be the single best cost predictor for military satellite communications. The historical data from the AEHF contractor showed that the weight had more than doubled since the program began and the majority of the weight growth was in the payload. The Air Force also used weight as a cost predictor, but attributed the weight growth to structural components rather than the more costly

payload portion of the satellite. When the CAIG briefed the Air Force on its estimate, the program office disagreed with the CAIG results, saying it did not see much payload weight growth in the data it analyzed. The CAIG reported that it used AEHF contractor cost reports to determine the amount of weight growth for the payload, and that these data were corroborated by AEHF monthly earned value management data, which showed cost overruns for the payload effort. As table 8 shows, the payload weight for the AEHF satellite increased about 116 percent.

Table 8: Historical AEHF Weight Growth

Milestone	Date	Payload weight (lbs)	Percent growth
Milestone I (A)	January 1999	1,694	n/a
Milestone II (B)	May 2001	2,631	55
Preliminary design review	August 2001	3,437	103
Critical design review	April 2004	3,659	116

Source: CAIG.

The Air Force attributed AEHF cost growth to problems to the cryptographic portion of the program, which is being developed by the National Security Agency (NSA). AEHF program officials stated that weight growth was consistent with that of other space programs. However, the CAIG stated that major cost growth was inevitable from the start of the AEHF program because historical data showed that it was possible to achieve a weight reduction or an increase in data capacity, but not both at the same time.

In addition, the CAIG also stated that the Air Force was optimistic in developing the AEHF schedule estimate. During the production decision review in 2004, the CAIG estimated the first satellite launch date to be 28 months longer than the program office estimate, which the CAIG estimated to have no more than a 1 percent chance of success. The CAIG also stated that because of problems with cryptographic development and reliability concerns with other technical aspects of the program, such as the phased array antenna and digital signal processing, the ambitious AEHF schedule was in jeopardy, and the program would not likely be implemented as planned.

In February 2005, the CAIG reviewed the proposed revision to the AEHF Acquisition Program Baseline (APB). In a memorandum sent to the Assistant Secretary of Defense for Network and Information Integration, the CAIG chairman did not concur with the AEHF draft APB. The CAIG

chairman explained that while the Air Force estimate included a 24 percent increase to the average procurement unit cost, which was 1 percent below the threshold for a Nunn-McCurdy certification, the CAIG's estimate prepared in December 2004 projected an increase of over 100 percent. Further, because of the vast differences between the Air Force and CAIG cost estimates, the CAIG chairman expressed concern that Congress would perceive the revised APB as an attempt to avoid a Nunn-McCurdy certification.

There is still risk for the AEHF program costs to grow. As a result of delays, AEHF satellites have not yet been through thermal vacuum testing. Spacecraft must endure a wide range of temperatures associated with liftoff and ascent through the atmosphere and exposure to the extreme temperatures of space. The thermal environment is generally considered the most stressful operating environment for hardware, and electronic parts are especially sensitive to thermal conditions. Problems such as cracks, bond defects, discoloration, performance drift, coating damage, and solder-joint failure have typically occurred. Thermal vacuum testing is used to screen out components with physical flaws and demonstrate that a device can activate and operate in extreme and changing temperatures. Because thermal vacuum testing provides the most realistic simulation of flight conditions, problems typically occur during testing. If this occurs on AEHF, more delays and cost overruns are likely.

NPOESS

NPOESS provides another example of where there were large differences between program office and independent cost estimates. In 2003, government decision makers relied on the program office's $7.2 billion cost estimate rather than the $8.8 billion independent cost estimate presented by the AFCAA to support the NPOESS development contract award. Program officials and decision makers preferred the more optimistic assumptions and costs of the program office estimate, viewing the independent estimate as too high. The $1.65 billion difference between the estimates is shown in table 9.

Table 9: Comparison of 2003 NPOESS Program Office and Independent Cost Estimates

Millions of fiscal year 2006 dollars				
	Independent cost estimate			
Program office estimate	AFCAA	CAIG	Delta	Latest program office estimate
$7,219	$8,869	[a]	23%	$11,400

Source: Air Force Cost Analysis Improvement Group briefing, April 2003.

Note: The program office and the AFCAA cost estimates were based on a purchase of six satellites, and the latest estimate is based on a purchase of four satellites, with less capability and a renewed reliance on a European contribution.

[a]The CAIG was not involved in preparing the 2003 independent cost estimate.

AFCAA based its estimate on an analysis of historical data from satellite systems (i.e., NASA's Aqua and Aura and DOD's Defense Meteorological Satellite Program [DMSP] program)[1] independent software and hardware models, and a risk simulation model using input from 30 independent engineers. The differences between the two estimates revolved around three major areas:

- The first included a discrepancy of almost $270 million in the cost for ground software development. The program office estimated the cost at $90 million based on the contractor's proposal for scaling the software and productivity rates that were highly optimistic. AFCAA based its estimate on a commercial software cost model using DSMP and SBIRS High historical software lines of code growth and actual productivity rates from the Global Positioning System program.

- The second difference was in the assembly and integration and testing estimates. Compared to actual integration efforts on historical satellites used by the AFCAA, the program office estimate to integrate the payloads onto the satellite bus was nearly $132 million less than AFCAA's estimate.

[1] Aqua collects information on evaporation from the oceans, water vapor from the atmosphere, radioactive energy fluxes, land vegetation cover, and land, air, and water temperatures, among other things. Aura's mission is to study the Earth's ozone, air quality, and climate focusing exclusively on the composition, chemistry, and dynamics of the Earth's upper and lower atmospheres. The Defense Meteorological Satellite Program collects weather data for military operations.

- The third area involved the systems engineering and program management costs for space segment development and production. AFCAA used actual data from the Aqua and Aura satellites, while the program office relied on the contractor's proposal—resulting in a difference of more than $130 million. The program office's estimate was lower based on an assumption that the costs for systems engineering and program management would be reduced by almost 50 percent between development and production. AFCAA stated concern that Aqua, Aura, and DMSP did not show a significant decrease in these costs over time.

Because the program office's estimate was lower, AFCAA concluded that the program office's cost and schedule estimates suffered from a lack of realism. However, the results of AFCAA's independent cost estimate were not used by the program office officials and decision makers.

In May 2004, the Under Secretary of the Air Force asked the CAIG to prepare an independent cost estimate for the NPOESS program. The estimate was completed in January 2005, following completion of the contractor's re-evaluation of the program baseline in November 2004. The cost estimate focused primarily on the proposed integration schedule of the NPOESS satellites. This estimate, like AFCAA's estimate before it, was based on historical cost data from analogous satellites and concluded that the program office's proposed integration schedule for the program was unrealistic. For example, the program office proposed an integration schedule for the first NPOESS satellite that was about half the time needed for an analogous satellite that had almost the same number of sensors. In other words, the NPOESS program estimated that it would integrate close to the same number of sensors in half the time. Table 10 illustrates how the program office developed its integration estimate for NPOESS, which was based on data from Aqua satellites.

Table 10: Program Office Integration Estimates for NPOESS

Program	Number of sensors	Months to integrate based on historical data	Months to integrate sensor	Deletion of months due to unforeseen problems	Months to integrate without problems	Months to integrate sensor without problems
Aqua	6	31	5.2	-17	14	2.3
NPOESS (first satellite integration)	5	26	5.2	N/A	14	2.8

Source: NPOESS Executive Committee briefing, January 2005.

The program office relied on actual data for Aqua, with no unforeseen problems as the basis for estimating the amount of time needed to integrate NPOESS sensors on the first satellite, rather than using historical data that would have yielded an estimate of 26 months to integrate five sensors. The program office and the contractor contended that a novel approach was being taken to satellite integration on the NPOESS program. The CAIG disagreed with this contention, stating that the proposed integration approach was not really novel because the use of a test bed model is a common tool used by satellite programs and would not yield the significant savings asserted by the program office. The CAIG, instead, estimated 25 months for integrating five sensors based on Aqua, Aura, and DMSP historical data. As a result, the CAIG's estimate was almost double the program office's. The CAIG also expressed concern to program officials that the integration schedule was severely underestimated and that the difference between the program office estimate and the CAIG's estimate was more than 6 years.

The program office's 2003 estimate of $7.2 billion has been shown to be highly unrealistic, with significant cost overruns and schedule delays—thus far—for sensor development only. Overall satellite integration efforts have been delayed due to the problems experienced in development of the sensors. In June 2006, the Office of the Secretary of Defense completed the Nunn-McCurdy process and certified a restructured program that reduced the number of satellites to be developed—from six to four, with the first launch being delayed to 2013 from 2009. Cost has grown from the original estimate of nearly $7.2 billion to over $11.4 billion—approximately a 60 percent increase.

SBIRS High

On the SBIRS High program, the program office and AFCAA predicted cost growth as early as 1996, when the program was initiated. While both estimates at that time were close ($5.7 billion in 2006 dollars by the program office and $5.6 billion in 2006 dollars by AFCAA), both were much more than the contractor's estimated costs. Nevertheless, the program was subsequently budgeted at $3.6 billion by the program office, almost $2 billion less than the AFCAA or program office estimate. The CAIG stated that the SBIRS program assumed savings under TSPR that simply did not materialize. SBIRS program officials also planned on savings from simply rehosting existing legacy software, but those savings were not realized because the all software eventually was rewritten. Instead, it took 2 years longer than planned to complete the first increment of software.

Savings were also assumed by the contractor in the area of systems engineering. The SBIRS High contractor initially estimated using fewer systems engineers, even though historical data showed programs similar to SBIRS High relied on three to almost four times the number of system engineers. Some of the tasks dropped from the systems engineering effort included verification and cycling of requirements because the government assumed that the contractor would perform these activities with little or no oversight. The contractor also held the same requirements for its subcontractors, resulting in a program with limited systems engineering. The lack of systems engineers has led to latent design flaws and substantially more integration and testing than planned because no one knew what had gone wrong when components began to fail during testing. This large amount of rework and troubleshooting has led to substantial cost and schedule increases.

In 2005, the CAIG reviewed the SBIRS High production program including estimating the cost to develop geosynchronous earth orbiting (GEO) satellites 3–5 as clones of GEOs 1 and 2 in order to determine the cost growth incurred by the production program since 2002. The CAIG's analysis projected a 25 percent Nunn-McCurdy breach in average procurement unit cost as a result of contractor cost and schedule performance being markedly worse than those experienced on historical satellite programs. In addition, the CAIG found that government actions to date have been ineffective in controlling cost and schedule growth. The program office, on the other hand, showed a much lower cost estimate for the production cost of GEO satellites 3-5, as seen in table 11.

Table 11: SBIRS High GEO 3–5 Procurement Funding Analysis

Millions of then-year dollars

Cost baseline	CAIG estimate	Program office	Delta	Delta %
Three individual satellite procurements	$2,892	$2,027	$865	43%

Source: CAIG and GAO analysis.

The CAIG based its estimate on contractor data for prime contractor systems engineering and program management, and payload integration assembly and test, which showed substantial increases in the period of performance, staffing levels, and hourly rates over initial estimates. In addition, the CAIG's estimate reflected a contractual change from a shared fee pool to a traditional prime contractor/subcontractor relationship.

The CAIG expressed concern that despite restructuring and rebaselining the program, SBIRS High has struggled unabated since contract award. The CAIG also cautioned that rebaselining would only allow the program to hide problems in the short term. For example, the CAIG reported that earned value management data showed GEO costs were following the same downward trend as the HEO portion of the program, which meant that additional cost and schedule delays were possible.

Appendix V: Comments from the Department of Defense

OFFICE OF THE ASSISTANT SECRETARY OF DEFENSE
6000 DEFENSE PENTAGON
WASHINGTON, DC 20301-6000

NETWORKS AND INFORMATION INTEGRATION

NOV 0 9 2006

Ms. Cristina T. Chaplain
Director, Acquisition and Sourcing Management
U.S. Government Accountability Office
441 G Street, NW
Washington, DC 20548

Dear Ms. Chaplain:

Thank you for the opportunity to comment on the GAO Draft Report, GAO-07-96 entitled "Space Acquisitions: DoD Needs to Take More Action to Address Unrealistic Initial Cost Estimates of Space Systems, dated October 13, 2006 (GAO Code 120554)". I concur with the overall findings of the report, and have enclosed comments to your specific recommendations.

Again, thank you for this opportunity to comment on your report.

Sincerely,

John R. Landon
Deputy Assistant Secretary of Defense
(C3ISR & IT Acquisition)

Enclosures:
As stated

GAO DRAFT REPORT DATED OCTOBER 13, 2006
GAO-07-96 (GAO CODE 120554)

"SPACE ACQUISITIONS: DOD NEEDS TO TAKE MORE ACTION TO ADDRESS UNREALISTIC INITIAL COST ESTIMATES OF SPACE SYSTEMS"

DEPARTMENT OF DEFENSE COMMENTS
TO THE GAO RECOMMENDATIONS

RECOMMENDATION 1: The GAO recommended that the Secretary of Defense direct the Under Secretary of Defense for Acquisition, Technology and Logistics or the Secretary of the Air Force, as appropriate, to increase accountability and transparency of decisions in space programs where an independent estimate produced by the Cost Analysis Improvement Group (CAIG) or Air Force Cost Analysis Agency (AFCAA) is not chosen, require officials involved in milestone decisions to document and justify the reasons for their choice and the differences between the program cost estimate and the independent cost estimate. (p. 21/GAO Draft Report)

DOD RESPONSE: Partially Concur. At both the development and the production Milestones for all Acquisition Category (ACAT) I programs U.S. Code Title 10 - Armed Forces requires the Milestone Decision Authority (MDA) [USD(AT&L)] to be informed by an independently developed life cycle cost estimate before making a decision on how to proceed. The OSD CAIG is charged with developing this estimate and, in practice, presents their findings to the Defense Acquisition Board (DAB) when they meet to advise the MDA. Additionally, the OSD CAIG formally documents its Independent Cost Estimate (ICE) in a report to the MDA. The complex decision to determine the cost figure used as a basis for funding and to evaluate future program performance must weigh many competing factors that are often qualitative in nature. As with all other acquisition related decisions, the decision is the MDA's alone, and although thoroughly discussed with the MDA advisors during the DAB meeting and clearly documented in the Acquisition Decision Memorandum (ADM), documenting the explicit justification will reduce the MDA's future decision-making flexibility.

RECOMMENDATION 2: The GAO recommended that the Secretary of Defense direct the Under Secretary of Defense for Acquisition, Technology and Logistics or the Secretary of the Air Force, as appropriate, to better ensure investment decisions for space programs are knowledge-based, instill processes and tools necessary to ensure lessons learned are incorporated into future estimates. (p. 21/GAO Draft Report)

DOD RESPONSE: Concur with this recommendation. DoD also concurs with the following recommendations in the report:

- Conducting post-mortem reviews of past space program cost estimates (program office and independent cost estimates) to measure cost estimating effectiveness and to track and record cost estimating mistakes.

DoD Response: Concur. The OSD CAIG has an established process whereby they meet with the key members of the National Security space cost analysis community to discuss and evaluate the outcomes following ACAT I space program Milestone or Key Decision Point (UDP) DAB-level reviews. The purpose of this meeting is to provide visibility to the other members of the National Security space cost analysis community on how the CAIG approaches ICE development and to give the community an opportunity to provide feedback to the CAIG on how to improve their processes. The OSD CAIG will work in the future to incorporate, within this existing framework, peer reviews of the associated program office estimate. The OSD CAIG, as required by the DoD's space acquisition regulations, tracks and documents their ICEs against current program office estimates as each ACAT I program proceeds through its development and production phases.

- Developing a centralized cost estimating database that provides realistic and credible data to cost estimators.

DoD Response: Concur. Several groups, including the OSD CAIG sponsored National Security Space Cost Analysis Symposium, Consortium on Space Technology Estimating Research (CoSTER), and the National Reconnaissance Office (NRO) led cost integrated process teams (IPTs), have been working to develop a database of historical space program costs available to the community as a whole for model development and estimate preparation. Additionally, the OSD CAIG in conjunction with USD(AT&L) and approved by the National Security space cost community, has reestablished a common space program work breakdown structure (WBS), incorporated in the latest version of Military Handbook 881, that supports the various estimating methodologies employed by the space cost community. This recently adopted standard will be used as a basis for all future space program cost data collection.

- Establishing protocols by which cost estimators working with the NRO can share data with the DOD space cost estimating community while still maintaining appropriate security over classified data.

DoD Response: Concur. Through the common database development process described above, the community, within security constraints, is working to make historical program cost data as widely available as possible.

- Ensuring estimates are updated as major events occur within a program that could have a material impact on cost, such as budget reductions, integration problems, hardware/software quality problems, etc.

DoD Response: Concur. Updating estimates, including independently developed cost estimates, more frequently than only at designated KDPs is clearly helpful to inform budgets and support program resource adjustment decisions. However, it is important not to mandate updates as, by their nature, they should be program and program phase dependent.

RECOMMENDATION 3: The GAO recommended that the Secretary of Defense direct the Under Secretary of Defense for Acquisition, Technology and Logistics or the Secretary of the Air Force, as appropriate, to optimize analysis and collaboration within the space cost estimating community, clearly articulate the roles and responsibilities of the various Air Force cost estimating organizations, and ensure that space system cost estimators are organized so that the Air Force can gain the most from their knowledge and expertise. In taking these actions for programs for which no independent estimate is developed by the DoD CAIG, consider assigning the Air Force Cost Analysis Agency (AFCAA) with responsibility for the development of independent cost estimates for space system acquisitions, since is outside the acquisition chain of command and therefore more likely to be unbiased and not pressured to produce optimistic estimates. (p. 21 GAO Draft Report)

DOD RESPONSE: Concur. The Air Force is currently updating their Cost and Economics Policy Directive (AFPD 65-5) and associated Instructions to further clarify the roles and responsibilities of their space cost analysis organizations. The purpose of this policy also addresses Air Force goals to optimize analysis and collaboration thus making the best use of the limited number of qualified and experienced space program cost analysts.

Appendix VI: GAO Contacts and Staff Acknowledgments

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Staff Acknowledgments

In addition to the contact named above, Brian Bothwell, Greg Campbell, Joanna Chan, Jennifer Echard, Art Gallegos, Barbara Haynes, Anne Hobson, Jason Lee, Sigrid McGinty, Karen Richey, Suzanne Sterling, Adam Vodraska, and Peter Zwanzig made key contributions to this report.

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